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Money and Capital in Interdependent Economies with Overlapping Generations

by
Frederick van der Ploeg

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Money and Capital in Interdependent Economies with Overlapping Generations

By Frederick van der Ploeg

CentER, Tilburg University and CEPR

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A two-country optimizing model with capital accumulation, purchasing power parity, floating exchange rates, uncovered interest parity, perfect foresight, finite lives and population growth is analysed. For the case of a zero birth rate, individuals are indifferent between tax finance and bond finance or money finance, so that Ricardian debt-neutrality and super-neutrality prevail. In general, a tax-financed increase in monetary growth leads to an interdependent Mundell–Tobin effect; that is, the world real interest rate falls and capital accumulation increases. A home monetary expansion leads in the long run to an increase in home consumption and net foreign assets. If the expansion occurs through open-market operations, money is super-neutral. Numerical methods are used to calculate the short-run and interim multipliers and to discuss the effects of imperfect substitution between home and foreign goods.

Introduction

It is well known that, in *ad hoc* macroeconomic *IS–LM–AS* models with capital accumulation, an increase in monetary growth leads to a smaller increase in the nominal interest rate and thus reduces the real interest rate and increases capital and output in the long run (Tobin, 1965). The main reason that money is not super-neutral is that money, in contrast to bonds, does not yield interest. However, the existence of such a Mundell–Tobin effect does not arise in standard optimizing models with infinitely lived consumers, as then the long-run real interest rate has to match the subjective rate of time preference (Sidrauski, 1967). Obviously, non-neutralities can occur during the transient path towards long-run equilibrium (Fischer, 1979a; Asako, 1983). Long-run non-neutralities occur when money enters the production function (Dornbusch and Frenkel, 1973; Fischer, 1974), when leisure enters the utility function in a non-separable fashion (Brock, 1974), when the residual mode of government finance is distortionary taxes, when there is population growth (Weil, 1989b), or when lives are finite (van der Ploeg and Marini, 1988). This paper focuses on the last two sources of non-neutrality, which stress the disconnectedness of individuals and provide a micro foundation of the Mundell–Tobin effect. It is assumed that there is a positive birth rate and no intergenerational bequest motive. This means that taxes can be passed on to future (yet unborn) generations, so that debt-neutrality (Barro, 1974) and super-neutrality (Sidrauski, 1967) no longer hold. Similar Mundell–Tobin effects have been found in conventional overlapping-generations models of a closed economy (e.g. Weiss, 1980; Drazen, 1981).

So far, the discussion of the effects of monetary growth on the real interest rate and capital accumulation has been concerned with closed economies. In small open economies the real interest rate is pegged to the world real interest rate and therefore there is no Mundell–Tobin effect. However, the world consists of interdependent economies and therefore a global Mundell-Tobin effect may be relevant. In an interdependent *ad hoc IS-LM-AS* world with floating exchange rates and perfect capital mobility, an increase in home monetary growth and inflation increases the home nominal interest rate, reduces the world real interest rate, and increases capital, output and employment both at home and abroad (van der Ploeg, 1990).[1] The objective of this paper is to reconsider these issues within the context of a two-country model with micro foundations, death and population growth. The advantage of such an approach is that careful account is taken of the intertemporal budget constraints of governments and private-sector agents and that a more satisfactory welfare analysis is feasible. The main findings are that Ricardian debt-neutrality and Sidrauski super-neutrality are intricately linked and that a tax-financed increase in monetary growth within the context of a macroeconomic model with micro foundations leads to a fall in capital accumulation throughout the world (the interdependent Mundell-Tobin effect). Some numerical simulation results are provided, which suggest that the magnitude of these effects is substantial.

This paper is not concerned with the effectiveness and spillover effects of fiscal policy in two-country overlapping-generations models. Frenkel and Razin (1986) discuss fiscal policy within the context of a global version of Blanchard's model of finite lives with a fixed labour force and fixed supplies of traded and non-traded goods while Giovannini (1988), Buiter (1986), van der Ploeg (1988b) and Obstfeld (1989) extend the two-country model to allow for capital accumulation. A related literature uses Buiter's (1981) two-country extension of Diamond's (1965) overlapping-generations model to analyse the welfare effects on the current old, domestic unborn, foreign unborn and current foreign young generations of debt policies—for example Persson (1985), who uses a single-good model and thus abstracts from the effects of aggregate demand on interest rates, and Fried and Howitt (1988), who use a similar model with a fixed supply of capital. Although there is already an extensive literature on the effects of fiscal policies in two-country overlapping models,[2] there has been no analysis of the effects of monetary policy in such two-country models so that the main objective of this paper is to provide such an analysis.

Section I develops a two-country model with floating exchange rates, uncovered interest parity and perfect foresight. Individuals have uncertain lifetimes and there is population growth. The asset menu consists of home equity, home money, and home and foreign government bonds. Section II considers the special case of a zero birth rate, which occurs when agents have infinite lives and there is no population growth. For this case any increase in non-human wealth arising from an increase in government debt is exactly offset by a reduction in human wealth arising from the future taxes required to pay off the additional government debt; hence Ricardian debt-neutrality prevails. Similarly, individuals are indifferent between money finance and tax finance and therefore Sidrauski super-neutrality holds. The Appendix decomposes the general two-country model into global averages and global differences, which simplifies the analysis considerably.

Section III considers joint and unilateral increases in monetary growth. When the residual mode of government finance is lump-sum taxation, one has an interdependent Mundell-Tobin effect. However, when the increase in monetary growth occurs through open-market operations, money is superneutral. The long-run effects of a home tax-financed increase in monetary growth are a fall in the world real interest rate, an increase in global activity, an increase in home consumption, a fall in foreign comsumption, an increase in home holdings of foreign assets, and a home balance-of-trade deficit. Section IV generalizes the model to allow for imperfect substitution between home and foreign goods and uses numerical simulation to compare the results with those under purchasing power parity (PPP) and to shed more light on transient effects. Section V concludes the paper.

I. A Two-country Overlapping-generations Model with Capital, Money and Government Debt

(a) Statement of the model

The world consists of two countries which are of equal size. The two countries have identical preferences, technologies and demographic structures, so that the only reasons for international trade in goods and financial assets are due to differences in fiscal or monetary policies. There is no currency substitution, so that money corresponds to a non-traded good. There are global markets for government bonds and equity on which there is risk-neutral arbitrage. It follows that capital, output and investment are the same in both countries. Labour is immobile and is thus a non-traded good. There is full employment in each country. There is a global market for goods, so that purchasing power parity holds, and there is a regime of floating exchange rates. There are overlapping generations, and there is no intergenerational bequest motive. Utility is a Cobb–Douglas function of the consumption of goods and real money balances, while labour supply is inelastic. Foreign variables are denoted with an asterisk. A two-country model can then be summarized as follows:

$$\dot{K} = f(K) - nK - \tfrac{1}{2}\gamma(U+U^*) - \tfrac{1}{2}(G+G^*), \qquad K(0) = K_0 \tag{1}$$

$$\dot{F} = [f'(K)-n]F + \tfrac{1}{2}\gamma(U^*-U) + \tfrac{1}{2}(G^*-G), \qquad F(0) = F_0 \tag{2}$$

$$\dot{U} = [f'(K)-\alpha]U - (n+\beta)(\alpha+\beta)(K+M+D+F), \qquad U(0) = \text{free} \tag{3}$$

$$\dot{U}^* = [f'(K)-\alpha]U^* - (n+\beta)(\alpha+\beta)(K+M^*+D^*-F), \qquad U^*(0) = \text{free} \tag{4}$$

$$\dot{M} = [f'(K)+\theta-n]M - (1-\gamma)U, \qquad M(0) = \text{free} \tag{5}$$

$$\dot{M}^* = [f'(K)+\theta^*-n]M^* - (1-\gamma)U^*, \qquad M^*(0) = \text{free} \tag{6}$$

$$\dot{D} = \{[f'(K)-n]D + G - \xi_0 - \theta M\}/(1-\xi_1), \qquad D(0) = D_0 \tag{7}$$

$$\dot{D}^* = \{[f'(K)-n]D^* + G^* - \xi_0^* - \theta^* M^*\}/(1-\xi_1), \qquad D^*(0) = D_0^* \tag{8}$$

where per capita state-space variables are the capital stock (K), net foreign assets (F), comprehensive consumption on home goods, foreign goods and real money balances (U), real money balances (M) and real government debt (D); the exogenous policy instruments are the rate of growth of the aggregate money supply (θ), the level of government spending (G) and the level of lump-sum taxation (ξ_0); the exogenous parameters are the rate of time preference (α), the probability of death (β), the rate of population growth (n), the share of the opportunity cost of holding real money balances in comprehensive spending (γ) and the responsiveness of taxes to the government deficit (ξ_1); and $f(K)$ denotes the intensive-form production function net of depreciation.

The capital stock, net foreign assets and government debt at home and abroad are predetermined, whereas comprehensive consumption and the price level (and thus M) at home and abroad are unconstrained by their past history. A perfect-foresight equilibrium assumes that all agents are on their demand and supply curves and that their expectations of future outcomes are rational, and satisfies all intertemporal accounting identities. It follows that the state-space variables depend on past values and on current and past expectations of current and future values taken on by the policy instruments. The solution of the model is discussed in the Appendix.

The real interest rate and the wage rate are given by $r=f'(K)$ and $w=f(K)-Kf'(K)$. Aggregate per capita production and gross investment are $Y=f(K)+\delta(K)$ and $I=Y-\frac{1}{2}\gamma(U+U^*)-\frac{1}{2}(G+G^*)$, where δ denotes the rate of depreciation. Consumption of goods is given by $C=\gamma U$. Inflation is given by $p=(1-\gamma)(U/M)-f'(K)$. Non-human wealth and human wealth are given by $A\equiv K+M+D+F$ and $H=U(\alpha+\beta)^{-1}-A$. Readers can move straight to Section II, but it is probably helpful to go through the detailed derivation of the model that is given in the remainder of this section.

(b) Finite lives and the individual's demand for goods and money balances

The demand side of each economy is made up of identical consumers with constant life expectancy. There is no intergenerational bequest motive, as in the analysis of Blanchard (1985) and Weil (1989a). The supply of labour at time t of a consumer born at time $s\le t$, $l(s,t)$, is inelastic, say $l(s,t)=1$. In general, lower-case letters denote the individual counterparts to the *per capita* population aggregates; for example, $c(s,t)$ denotes consumption at time t of a consumer born at time $s\le t$. The consumer has Cobb–Douglas preferences over the consumption of private goods, real money balances and the consumption of public goods. Feenstra (1986) provides a justification, based on liquidity costs, for entering money in the utility function. The consumer faces the following optimization problem:

$$(9)\qquad \max_{c,m}\int_t^{\infty}\log\{[c(s,v)^{\gamma}m(s,v)^{1-\gamma}]g(v)^{\gamma'}\}\times\exp[(\alpha+\beta)(t-v)]\,dv,\qquad 0<\gamma<1,$$

subject to the individual consumer's flow budget constraint,

$$(10)\qquad \frac{da(s,t)}{dt}=[r(t)+\beta]a(s,t)+w(t)l(s,t)-z(s,t)-c(s,t)-[r(t)+p(t)]m(s,t),$$

and the condition precluding Ponzi games,

$$(11)\qquad \lim_{v\to\infty}\exp\left\{-\int_t^{v}[r(\mu)+\beta]\,d\mu\right\}a(v,t)=0,$$

where $z(s,t)$ denotes lump-sum taxation at time t of a consumer born at time s. The individual consumer receives (pays), for every period of his life, a premium $\beta a(s, t)$, and at the time of death the individual's net wealth (debt) goes to (is cancelled by) the life insurance company. The premium is actuarially fair, so that this formulation corresponds to efficient life insurance or annuities markets. Since the probability of death and the premium are equal to β, the subjective rate of time preference and the real rate of return are effectively increased by this amount.

Comprehensive spending is defined as consumption of goods plus interest forgone on money holdings; that is,

$$u(s, t) \equiv c(s, t) + [r(t) + p(t)]m(s, t). \tag{12}$$

The optimization then yields $c(s, t) = \gamma u(s, t)$, $m(s, t) = (1-\gamma)u(s, t)/[r(t) + p(t)]$ and the 'tilt' of the comprehensive consumption function,

$$du(s, t)/dt = [r(t) - \alpha]u(s, t).$$

Note that the individual consumer ensures that the marginal rate of substitution between goods and real money balances equals the opportunity cost of holding real money balances, i.e. the nominal interest rate, and that the semi-elasticity of money demand with respect to the nominal interest rate is unity. If one defines human wealth as the present discounted value of expected after-tax wage income,

$$h(s, t) \equiv \int_t^{\infty} [w(v)l(s, v) - z(s, v)] \exp\left\{-\int_t^{v} [r(\mu) + \beta]\, d\mu\right\} dv, \tag{13}$$

where the discount rate equals the real interest rate plus the probability of death, one can write comprehensive spending as

$$u(s, t) = (\alpha + \beta)[a(s, t) + h(s, t)]. \tag{14}$$

The consumption function is linear in human plus non-human wealth, because the intertemporal elasticity of substitution is assumed to be unity. This assumption facilitates the aggregation across individuals born at the same instant. Blanchard (1985) discusses the implications of general isoelastic utility functions for non-monetary economies.

(c) *Aggregation across individuals and population growth*

Buiter (1988) extends the aggregation procedure of Yaari (1965) and Blanchard (1985) to allow for population growth and extends the aggregation procedure of Weil (1989a) to allow for finite lives. This extension allows for overlapping families of finitely lived individuals and is applied here.

At each instant a new cohort is born. The size of each cohort grows at a constant rate, so that the size of the cohort born at time t equals $(n+\beta)\exp(nt)$. The size at time t of the surviving cohort born at time $s \le t$ equals $(n+\beta)\exp(ns)\exp[-\beta(t-s)]$, since β is the probability of death. The total population at time t equals $(n+\beta)\int_{-\infty}^{t} \exp(ns)\exp[-\beta(t-s)]\, ds = \exp(nt)$. The per capita population aggregate for, say, consumption is defined as

$$C(t) \equiv (n+\beta) \int_{-\infty}^{t} c(s, t) \exp[(n+\beta)(s-t)]\, ds, \tag{15}$$

because the population aggregate is obtained as the sum of consumption of all surviving cohorts at time t, $c(s, t)$, $s \le t$, times the size of the surviving cohort, $(n+\beta)\exp(ns)\exp[-\beta(t-s)]$ and the *per capita* population aggregate is obtained by dividing the population aggregate by the population size, $\exp(nt)$. Other *per capita* population aggregates are obtained in a similar manner and are denoted by capital letters.

Application of this aggregation procedure yields

(16) $$C(t)=\gamma U(t)$$

(17) $$M(t)=(1-\gamma)U(t)/[r(t)+p(t)]$$

(18) $$\dot{U}(t)=[r(t)-\alpha]U(t)-(n+\beta)(\alpha+\beta)A(t)$$

(19) $$\dot{A}(t)=[r(t)-n]A(t)+w(t)-Z(t)-U(t).$$

The derivation of (19) used the fact that, in the absence of bequests, the non-human wealth of newly born individuals must be zero: $a(t,t)=0$. Unlike (10), (19) no longer contains a life insurance premium as this effectively constitutes a transfer from those who die to those who survive and therefore does not affect the return on aggregate non-human wealth. Aggregation of human wealth, (13), yields $\dot{H}=(r+\beta)H-w+Z$. Upon substitution of this and the aggregate consumption function, $U=(\alpha+\beta)(A+H)$, into (19), one obtains the 'tilt' of the aggregate comprehensive consumption function, (18).

(*d*) *Production*

The production side of each economy follows from a concave and twice differentiable constant-returns-to-scale production function, $y(t)=\bar{f}(k(t),l(t))$ where $l(t)$ denotes employment at time t. The value of the firm, v, follows from the condition for risk-neutral arbitrage between equity and other financial assets; that is, $rv=\dot{v}^e+(y-wl-i)$. Hence shareholders equate the return on equity, i.e. capital gains plus dividends, to the real return on alternative assets. Integration of this arbitrage condition gives an expression for the value of the firm,

(20) $$v(t)=\int_t^{\infty}[\bar{f}(k(v),l(v))-w(v)l(v)-i(v)]\exp\left[-\int_t^{v}r(\mu)\,\mathrm{d}\mu\right]\mathrm{d}v,$$

which simply represents the present discounted value of future profits. Maximization of the value of the firm subject to the capital accumulation condition, $\dot{k}=i-\delta k$, yields $\bar{f}_l(k,l)=w$ and $\bar{f}_k(k,l)=r+\delta$. In other words, the marginal product of labour equals the real wage and the marginal product of capital equals the user cost of capital, i.e. the rental charge plus depreciation charge minus capital gains. There are no adjustment costs associated with investment, so that Tobin's 'Q' is unity and therefore $v=k$. Labour market equilibrium gives $l(t)=\exp(nt)$. In *per capita* units, one has $f'(K)=r$, $f(K)-Kf'(K)=w$ and $\dot{K}=I-(\delta+n)K$, $K(0)=K_0$, where $K(t)\equiv k(t)\exp(-nt)$, $I(t)\equiv i(t)\exp(-nt)$ and net *per capita* output is given by $f(K)\equiv\bar{f}(K,l)-\delta K$.

The excess of net output over wages plus dividends, $\pi\equiv\bar{f}(K,l)-w-I$, must equal the capital gains on equity, that is $f(K)-\pi-w=\dot{V}^e+nV$. Since $f(K)=rK+w$, one has the arbitrage condition $\pi+\dot{V}^e=(r-n)V$.

(*e*) *Financial assets and the government budget constraint*

The asset menu of consumers consists of home cash, home government bonds, foreign government bonds and home (and foreign) equity. Since home equity, home government bonds and foreign government bonds are perfect substitutes, the results also hold for the case when there is international trade in equities. Hence there is no currency substitution and money can be treated as a non-traded good. Home and foreign government bonds are perfect substitutes, so that non-human wealth corresponds to $A \equiv M + B + V$ where B denotes the *per capita* holdings of home and foreign government bonds by home individuals. The government spends on goods, levies lump-sum taxes and finances the deficit by printing money or issuing government debt. This is captured by the government budget constraint,

$$(21) \qquad \dot{D} = (r-n) + G - Z - \theta M, \qquad D(0) = D_0,$$

where $G(t) = g(t)\exp(-nt)$ denotes *per capita* government spending at time t. Seigniorage revenues are represented by the term θM. Integration of (21) and application of the solvency (no-Ponzi-games) condition yields

$$(21') \qquad D(t) = \int_t^\infty [Z(v) + \theta(v)M(v) - G(v)] \exp\left\{-\int_t^v [r(\mu) - n]\,\mathrm{d}\mu\right\} \mathrm{d}v,$$

so that the current real government debt has to be paid off by the present discounted value of the excess of future lump-sum taxes and seigniorage revenues over government spending.

Equilibrium in the money market is represented by[3]

$$(22) \qquad \dot{M} = (\theta - p - n)M, \qquad M(0) = \text{free}.$$

Since the economies are classical without any rigidities, the price level clears the goods markets and depends on expected future events. This implies that the initial price level and the initial *per capita* holdings of real money balances, $M(0)$, are free to jump.

Each government has four policy instruments—G, Z, θ and D—of which three can be chosen freely and the fourth follows residually from the government budget constraint. Under bond finance it is assumed that G and θ are exogenous policy instruments, Z is an endogenous policy instrument and follows from a feedback rule, and D follows from the government budget constraint. A feedback rule for lump-sum taxation is required, because in the absence of such a rule the solvency of the government is not ensured. A sensible tax rule is

$$(23) \qquad Z = \xi_0 - \xi_1 \dot{D} + \xi_2 D,$$

so that taxes are raised when the real government debt is high or when there is a government surplus. Solvency usually requires

$$\partial \dot{D}/\partial D = (r - n - \xi_2)/(1 - \xi_1) < 0,$$

so that either $\xi_2 > r - n$ and $\xi_1 = 0$ or $\xi_2 = 0$ and $\xi_1 > 1$ is assumed. Note that, for $\xi_2 = 0$, a long-run increase in taxation, ξ_0, is preceded by a short-run cut in taxation, $Z = \{-\xi_0 + \xi_1[(r-n)D + G - \theta M]\}/(\xi_1 - 1)$. Obviously, an increase in government spending or fall in seigniorage revenues requires an increase in taxation. The case of tax finance ($\dot{D} = 0$) corresponds to $\xi_1 \to \infty$, so that $Z = (r-n)D_0 + G - \theta M$. From now on, it will be assumed that the tax rule is given by $Z = \xi_0 - \xi_1 \dot{D}$ (i.e. $\xi_2 = 0$). Note that only the aggregate level of lump-sum taxes matters for the aggregate per capita variables, so that the distribution of taxes across generations does not affect aggregate *per capita* variables.

(*f*) *The international context*

The foreign country has analogous relationships to the ones discussed in Sections (b)-(e) above. There is no labour mobility between the two countries and there is no international market for equity. However, there are efficient international markets for goods and government bonds. In fact, it is assumed that there is perfect substitution between home and foreign products as well as between home and foreign government bonds. Hence (relative) purchasing power parity, $p(t)=p^*(t)+e(t)$ (where $e(t)$ denotes the rate of depreciation of the nominal exchange rate at time t), and uncovered interest parity, $r(t)+p(t)=r^*(t)+p^*(t)+e^e(t)$ (where $e^e(t)$ denotes the expected rate of depreciation of the nominal exchange rate at time t), must hold. Together with the assumption of perfect foresight, one has equalization of real interest rates, $r(t)=r^*(t)$. It follows from $f'(K)=f'(K^*)=r$ that the home and foreign capital stocks must also be the same, i.e. $K=K^*$, and that therefore wage rates must be the same, $w=w^*$.

The Law of One Price implies that there is a world market for goods for which the equilibrium condition is

$$(24) \qquad Y+Y^*=C+C^*+I+I^*+G+G^*,$$

where $Y=\bar{f}(K,1)$ denotes *per capita* gross output. Net holdings of foreign assets are the excess of private-sector holdings of bonds over government debt, that is $F\equiv B-D$. The condition for equilibrium in the world market for government bonds is $B+B^*=D+D^*$ or $F^*=-F$. The balance of trade is the excess of domestic production over domestic absorption, $Y-C-I-G$. Together with interest on net foreign assets, it gives the current account,

$$(25) \qquad \dot{F}=(r-n)F+Y-C-I-G, \qquad F(0)=F_0,$$

which equals the increase in wealth of the nation. Note that subtraction of $\dot{K}=I-(\delta+n)K$, (21) and (22) from (19) yields (25). Application of the country's solvency (no-Ponzi-games) condition gives

$$(25') \qquad F^*(t)=\int_t^{\infty}[Y(v)-C(v)-I(v)-G(v)] \times \exp\left\{-\int_t^{v}[r(\mu)-n]\,\mathrm{d}\mu\right\}\mathrm{d}v,$$

so that the current debt of the nation eventually has to be paid off by future savings' surpluses of the government and private sector (i.e. by future balance of trade surpluses).

II. Super-neutrality and Debt-neutrality

Since the death rate is β and the population growth rate is n, the birth rate must equal $n+\beta$. The birth rate is exactly the wedge between the discount rate used to calculate human wealth, $r+\beta$, and the discount rate used to calculate government debt, $r-n$. If the birth rate is zero, this wedge is zero and therefore it is no longer possible for society to pass taxes on to future generations. This implies that individuals are indifferent between tax finance and bond finance of the government deficit, because an increase in government debt has to be paid off by future taxes and the discounted value of these taxes reduces human wealth by exactly the same amount as non-human wealth is increased. Hence Ricardian debt-neutrality (*cf.* Barro, 1974) prevails when the birth rate is zero.

For a zero birth rate, one has $U = U^*$; also,

(26) $\dot{K} = f(K) - nK - \gamma U - \tfrac{1}{2}(G + G^*), \qquad K(0) = K_0$

(27) $\dot{F} = [f'(K) - n]F + \tfrac{1}{2}(G^* - G), \qquad F(0) = F_0$

(28) $\dot{U} = [f'(K) - \alpha]U, \qquad U(0) = \text{free}.$

Clearly, increases in monetary growth (induced by open-market operations) at home or abroad (θ, θ^*) have no effect on the real interest rate, capital, output, consumption of goods or investment, and therefore super-neutrality (*cf.* Sidrauski, 1967) holds. They increase the inflation and nominal interest rates one-for-one and thus reduce holdings of real money balances, so that economic welfare falls. Real seigniorage revenues increase (see equation (32) below), which permits the servicing of a greater government debt as lump-sum taxes are unaffected. In fact, the fall in non-human wealth caused by the fall in real money balances is exactly offset by the increase in non-human wealth caused by the increase in holdings of bonds, so that total wealth and consumption are unaffected. Super-neutrality of monetary growth also holds when lump-sum taxes rather than bonds are the residual mode of government finance. In that case, the fall in non-human wealth is exactly offset by the increase in human wealth caused by the fall in lump-sum taxes.

It is easy to show that, for a zero birth rate, $\mathrm{d}K(\infty)/\mathrm{d}G = \mathrm{d}K^*(\infty)/\mathrm{d}G = 0$, $\mathrm{d}C(\infty)/\mathrm{d}G = \mathrm{d}C^*(\infty)/\mathrm{d}G = -\tfrac{1}{2}$ and $\mathrm{d}F(\infty)/\mathrm{d}G = \tfrac{1}{2}(\alpha - n)$, so that any increase in real government spending is completely crowded out by a reduction in private consumption and therefore has no effect on the real interest rate, capital stock or output. The associated trade deficits imply a transient foreign debt, but in the long run must be associated with net foreign assets (if $n < \alpha$). More importantly, the transient and steady-state effects of government spending on capital, output and consumption do not depend on whether it is financed by money, bonds or taxes. Bond finance today is not perceived as an increase in private-sector wealth, because the discounted value of the future lump-sum or inflation taxes required to pay off the debt exactly equals today's increase in government debt. It is also obvious that, when the birth rate is zero, changes in lump-sum taxation have no real effects.

Note that the death rate is irrelevant for these neutrality results. For example, economies with a positive death rate and a zero birth rate ($\beta = -n > 0$) have a declining population and are characterized by super-neutrality and debt-neutrality as well.

In the light of the above discussion, it may be useful to relate the two-country model presented in Section I to some previous models. If one assumes zero population growth, infinite lives and no government debt ($n = \beta = D = D^* = 0$), the present model corresponds to a two-country extension of the money capital, closed-economy model developed by Sidrauski (1967). In such a world long-run super-neutrality holds; that is, monetary growth is unable to affect the steady-state outcomes of real variables, although (for weakly non-separable rather than Cobb–Douglas preferences) there may be short-run neutralities (Fischer, 1979b; Asako, 1983). If one assumes zero population growth, finite lives and no government debt ($n = D = D^* = 0$), the present model corresponds to a two-country extension of the closed-economy model developed by Marini and van der Ploeg (1988). In that case, an increase in monetary growth with lump-sum taxes as the residual mode of government finance reduces the real interest rate, increases capital, increases seigniorage revenues (and therefore reduces lump-sum taxes by the same amount), increases both human and total wealth, and increases the consumption of goods. Finite lives clearly destroy the super-neutrality result. Similarly, an increase in government spending increases the interest rate, reduces capital, real money balances, human wealth and non-human wealth, increases lump-sum taxation, reduces seigniorage revenues, and leads to more than 100 per cent crowding-out of private consumption. If one assumes positive population growth and infinite lives ($\beta = 0$), the present model corresponds to a two-country extension of the closed-economy model developed by Weil (1989b). Weil finds that population growth alone is sufficient to destroy the long-run super neutrality of monetary growth. The reason is, of course, that the government can tax both those individuals currently alive and those yet to be born. In fact, it has already been argued above that a necessary and sufficient condition for super-neutrality is that the total birth rate is zero.

Blanchard (1985) shows, for a closed economy without money but with capital, that finite lives and the absence of an intergenerational bequest motive destroy Ricardian debt-neutrality, and Weil (1989a) shows the same for population growth. Buiter (1988) shows, for a closed economy without money and capital, that a necessary and sufficient condition for Ricardian debt-neutrality is that there is no intergenerational bequest motive and that the total birth rate, i.e. the sum of the population growth rate and the probability of death, must be zero. Or course, Barro (1974) also discusses that, without bequests, models with finitely lived consumers have non-neutrality of government debt. The contribution of Blanchard (1985), Weil (1989a) and Buiter (1988) is simply to provide models without bequests that are easier to manipulate than the Diamond-type overlapping-generations models without bequests.

III. Monetary Policy

(a) *Steady-state effects of a joint increase in monetary growth*

The case of tax finance is considered first. This means that seigniorage is rebated to agents in a lump-sum manner through helicopter drops of money. The relevant steady-state, tax-financed multipliers for multilateral increases in monetary growth are given by (see Appendix):

$$(29)\qquad [\mathrm{d}K^u(\infty)/\mathrm{d}\theta^u]_{TF} = -(n+\beta)(\alpha+\beta)\gamma M/\Delta^u_{TF} \geq 0$$

$$(30)\qquad [\mathrm{d}U^u(\infty)/\mathrm{d}\theta^u]_{TF} = -(n+\beta)(\alpha+\beta)(r-n)M/\Delta^u_{TF} \geq 0$$

$$(31)\qquad [\mathrm{d}M^u(\infty)/\mathrm{d}\theta^u]_{TF}$$

$$= -M\{\gamma Uf'' - (n+\beta)(\alpha+\beta)[((w-Z)/U)-(1-\gamma)]\}/\Delta^u_{TF}$$

$$(\leq -\gamma MUf''/\Delta^u_{TF} < 0),$$

so that $[\mathrm{d}r(\infty)/\mathrm{d}\theta^{a}]_{TF} = -(n+\beta)(\alpha+\beta)\gamma M f''/\Delta^{a}_{TF} \leq 0$. Hence, as long as the total birth rate is positive, a joint increase in monetary growth leads in the long run to a one-for-one increase in inflation, an increase in nominal interest rates, a fall in the world real interest rate, increases in global capital, output and consumption of goods, and a fall in real money balances. These multipliers remind one of the conventional Mundell–Tobin effect, yet they are derived from a general equilibrium model with micro foundations. This breakdown of super-neutrality arises because a positive birth rate drives a wedge between the discount rate used to calculate human wealth and the one used to calculate government debt, and therefore drives a wedge between the real interest rate and the rate of time preference.

The steady-state effect on real seigniorage revenues is given by

$$(32)\qquad [\mathrm{d}\theta^{a}M^{a}(\infty)/\mathrm{d}\theta^{a}]_{TF} = \{\gamma(r-n)Uf'' + (n+\beta)(\alpha+\beta)[\gamma Mf'' - (r-n)(w-Z)/U]\}(M/\Delta^{a}_{TF}) > 0,$$

hence an increase in global monetary growth raises seigniorage revenues (despite a fall in real money balances) and therefore reduces lump-sum taxes. Human wealth increases, because lump-sum taxes fall and because (with a positive birth rate) wage income increases and the real interest rate falls. The increase in human wealth more than offsets any fall in non-human wealth, so that total wealth and consumption of goods rises. Obviously, joint increases in monetary growth have no effects on net foreign assets.

The increase in the consumption of goods increases global welfare, while the increase in inflation and fall in real money balances reduce global welfare, so that the net effect on global welfare is ambiguous.

The above micro foundation of the Mundell–Tobin effect contrasts with Sidrauski's (1967) result on super-neutrality. This result holds for tax-financed increases in monetary growth, but not for bond-financed increases in monetary growth even when the birth rate is positive (see Appendix):

$$(33)\qquad [\mathrm{d}K^{a}(\infty)/\mathrm{d}\theta^{a}]_{BF} = [\mathrm{d}U^{a}(\infty)/\mathrm{d}\theta^{a}]_{BF} = [\mathrm{d}r(\infty)/\mathrm{d}\theta^{a}]_{BF} = 0$$

$$(34)\qquad [\mathrm{d}M^{a}(\infty)/\mathrm{d}\theta^{a}]_{BF} = \left(\frac{\xi M}{\Delta^{a}}\right)\{(r-n)\gamma Uf'' - (n+\beta)(\alpha+\beta)[((r-n)(w-Z)/U) - \gamma f''(D+M)]\} < 0.$$

It is not surprising that under bond finance changes in monetary growth do not affect real outcomes in the long run, because lump-sum taxes and therefore human wealth are unaffected by bond finance in the long run ($Z = \xi_0 - \xi_1\dot{D} = \xi_0$). Therefore it does not matter that the birth rate drives a wedge between the discount rate used to calculate human wealth and the one used to calculate the government debt, so that real outcomes are unaffected in the long run. The optimal monetary policy is then for each government to implement Friedman's (1969) full liquidity rule, that is, to drive the nominal interest rates to zero and the holdings of real money balances to infinity by setting the monetary growth rates to the difference between the population growth rate and the rate of time preferences ($\theta = \theta^* = n - \alpha$). Obviously, when the tax rule depends on the stock of government debt (say, $Z = \xi_0 + \xi_2 D$), monetary growth affects lump-sum taxation and thus real outcomes in the long run.

When the total birth rate is zero ($n + \beta = 0$), the effects on real money balances and seigniorage revenues are exactly the same as with tax-financed monetary growth. Since seigniorage revenues increase, the government can afford to service larger stocks of government debt. There are no effects on total (human plus non-human) wealth. This reflects the Ricardian debt equivalence proportion (e.g. Barro, 1974), because the increase in human wealth arising from the reduction in taxes under the tax-financed increase in monetary growth is exactly the same as the increase in bonds under the bond-financed increase in monetary growth. Hence, for $n + \beta = 0$, one has

$$(35) \qquad [\mathrm{d}B^a(\infty)/\mathrm{d}\theta^a]_{BF} = [\mathrm{d}H^a(\infty)/\mathrm{d}\theta^a]_{TF} = -[\mathrm{d}M(\infty)/\mathrm{d}\theta^a]_{BF,TF} = \frac{M}{\alpha + \theta - n} > 0.$$

Also, when the birth rate is zero, the long-run effects on social welfare are independent of the residual mode of finance.

Finally, when the birth rate is positive and preferences are non-separable in consumption and real money balances, bond-financed monetary growth can have real effects in the long run (*cf.* Marini and van der Ploeg, 1988). The reason is that monetary growth affects the nominal interest rate, which in turn affects the proportion spent on consumption of goods. Bond-financed increases in monetary growth decrease (increase) capital and consumption when the elasticity of substitution between goods and real money balances is less (greater) than unity.

(*b*) *Steady-state effects of a unilateral increase in monetary growth*

Again, the case of helicopter drops of subsidies (tax finance) is considered first. The relevant steady-state, tax-financed multipliers for unilateral increases in monetary growth are (see Appendix):

$$(36) \qquad [\mathrm{d}F(\infty)/\mathrm{d}\theta^d]_{TF} = -\tfrac{1}{2}(n+\beta)(\alpha+\beta)\gamma M/\Delta^d_{TF} > 0$$

$$(37) \qquad [\mathrm{d}U^d(\infty)/\mathrm{d}\theta^d]_{TF} = -(n+\beta)(\alpha+\beta)(r-n)M/\Delta^d_{TF} > 0$$

$$(38) \qquad [\mathrm{d}M^d(\infty)/\mathrm{d}\theta^d]_{TF} = (n+\beta)(\alpha+\beta)M[((w-Z)/U)-(1-\gamma)]/\Delta^d_{TF} < 0.$$

The Appendix shows that, as far as steady-state consumption is concerned, an increase in monetary growth is a beggar-thy-neighbour policy; i.e. $[\mathrm{d}U(\infty)/\mathrm{d}\theta]_{TF} > 0$, $[\mathrm{d}U^*/\mathrm{d}\theta]_{TF} < 0$. The Appendix also shows that an increase in monetary growth reduces holdings of real money balances at home by more than abroad: $0 > [\mathrm{d}M(\infty)/\mathrm{d}\theta]_{TF} < [\mathrm{d}M^*(\infty)/\mathrm{d}\theta]_{TF}$.

For the case of a zero birth rate, global monetary growth is super-neutral and therefore does not affect average consumption. It follows that the positive effect of home monetary growth on home consumption is exactly offset by the negative effect on foreign consumption

$$[\mathrm{d}C(\infty)/\mathrm{d}\theta]_{TF} = -[\mathrm{d}C^*(\infty)/\mathrm{d}\theta]_{TF} > 0, \qquad n+\beta=0.$$

In general, the birth rate is positive, unilateral monetary growth is non-neutral, and therefore the positive effect on home consumption outweighs the negative effect on foreign consumption.

The increase in home monetary growth rate, in general ($n+\beta>0$), leads to an equal increase in home inflation ($p=\theta\uparrow$), a (smaller) increase in the home nominal interest rate ($r+p\uparrow$) and a fall in the world real interest rate ($r=r^*\downarrow$). This increases capital accumulation and output, both at home and abroad ($K=K^*\uparrow$, $Y=Y^*\uparrow$). This is the two-country version of the Mundell-Tobin effect. Foreign inflation is unaffected. This means that each country has an incentive to transfer the burden of reducing the world real interest rate and increasing world activity to the other country, because then it does not need to increase its own monetary growth and inflation rate while it does enjoy the increase in activity (*cf.* van der Ploeg, 1990).

Since the opportunity cost of holding money balances increases at home and decreases abroad ($r^*+p^*\downarrow$), it is relatively less attractive for home agents to hold money than it is for foreign agents. There is, therefore, an incentive for home agents to buy bonds from foreign agents ($B\uparrow$, $B^*\downarrow$), so that the home (foreign) country accumulates foreign assets (debt) ($F\uparrow$). The interest payments on net foreign assets allows the home country to run a balance of trade deficit, so that in the long run home agents can afford to consume more than foreign agents (C, $U\uparrow$, C^*, $U^*\uparrow$).

Hence, even though there is a positive spillover effect of home monetary growth on foreign capital and output, there is a negative spillover effect on foreign consumption of goods, and this decreases foreign social welfare. The net effect on foreign social welfare depends on what happens to foreign holdings of real money balances. The lower opportunity cost of holding foreign money balances tends to increase it, while the lower levels of foreign total consumption and total wealth tend to decrease it, so that the net effect on holdings of foreign money balances is ambiguous ($M^*\uparrow\downarrow$). For small (large) values of the birth rate, foreign money balances decline (increase) and therefore foreign social welfare unambiguously decreases (might increase).

Seigniorage revenues at home increase ($\theta M\uparrow$), which allows the home government to cut taxes ($Z\downarrow$). Human wealth of home agents increases, because the wage increases ($w\uparrow$), lump-sum taxes fall and the real interest rate falls. Non-human wealth of home agents can decrease when the fall in home real money balances outweighs the increase in home equity and bondholdings, but any fall must be dominated by the increase in human wealth as total wealth of home agents increases ($A+H\uparrow$). The effect on foreign seigniorage revenues is ambiguous ($\theta^*M^*\downarrow\uparrow$), so that the effect on foreign taxes and human wealth is ambiguous. The effect on foreign non-human wealth is also ambiguous, because the fall in foreign bondholdings may or may not be outweighed by the increase in foreign equity and the possible increase in foreign real money balances. However, total foreign wealth decreases ($A^*+H^*\downarrow$).

Now consider the case of bond finance ($\xi>0$). A unilateral bond-financed increase in monetary growth has no effect on real activity (see equation (33)) and, similarly, it has no effect on net foreign assets in the long run ($[\mathrm{d}F(\infty)/\mathrm{d}\theta]_{BF}=0$). The reason is again that long-run taxation is unaffected.

(*c*) *Dynamic policy simulation*

Table 1 presents the parameter values that have been used in the numerical simulation exercises presented in Table 2. It has been assumed that the average lifetime is 50 periods, that the pure rate of time preference and the rate of population growth are 2 per cent, that the share of pre-tax labour income in value added is 80 per cent, that the share of imports in total consumption is 25 per cent, and that increases in the supply of money are distributed through lump-sum subsidies (tax finance). The model has been linearized around the symmetric steady state associated with 7 per cent inflation and a level of government spending and lump-sum taxes equal to, respectively, 20 and 7·9 per cent of the national income. This corresponds to a steady-state *per capita* primary deficit, seigniorage revenues and public debt of, respectively, 12·1, 13·5 and 134·6 per cent of the national income. Steady-state human wealth corresponds to about 14 times the national income. The eigenvalues of the linearized model are real and satisfy the saddlepoint property. The global averages take about 35 periods ($-\ln(0{\cdot}001)/0{\cdot}1991$), whereas the global differences take about 253 periods to settle down within 0·1 per cent of the steady-state values. The slow adjustment of the global differences is due mainly to the sluggish nature of the current-account dynamics.

Table 2 shows the impact and steady-state effects of a tax-financed increase of 10 percentage points in monetary growth at home and abroad. Since it is a joint increase, there is no effect on the balance of trade, the current account or the accumulation of foreign assets. In the long run, the real interest rate falls by 0·46 percentage points, so that the capital stock increases by 4·45 per cent and output and the real wage by 0·89 per cent. However, on impact these variables are unaffected. The inflation rate jumps up on impact by 9·54 percentage points and then gradually rises to 10 percentage points. This

TABLE 1

NUMERICAL SPECIFICATION

Parameter values

$\alpha=\beta=n=0{\cdot}02;\ \delta=0{\cdot}1;\ \bar{f}(K,l)=0{\cdot}65K^{0{\cdot}2};\ \gamma=0{\cdot}08;\ \omega=0{\cdot}75;$
$\xi=0{\cdot}0;\ \xi_0=0{\cdot}05125;\ G=G^*=0{\cdot}13;\ \theta=\theta^*=0{\cdot}07$

Steady state (symmetric)

$w=0{\cdot}52;\ r=0{\cdot}03;\ p=0{\cdot}05;\ r+p=0{\cdot}08;$
$C=0{\cdot}4;\ I=0{\cdot}12;\ Y=0{\cdot}65;\ f(K)=0{\cdot}55;\ V=K=1{\cdot}0;$
$H=9{\cdot}375;\ A=3{\cdot}125;\ M=1{\cdot}25;\ D=B=0{\cdot}875;\ F=0;$
$\theta M=0{\cdot}0875;\ G-\theta M=0{\cdot}0425;\ Z=0{\cdot}05125;$
$U=0{\cdot}5;\ \gamma\log(C)+(1-\gamma)\log(M)=-0{\cdot}6884.$

Eigenvalues: tax finance and purchasing power parity

−0·1991, 0·0838 and 0·2153 for the global averages;
−0·0273, 0·0418 and 0·0855 for the global differences.

Eigenvalues: tax finance and imperfect substitution

−0·1991, 0·0838 and 0·2153 for the global averages;
−0·3170, −0·0184, 0·0324, 0·0848 and 0·2153 for the global differences.

TABLE 2

EFFECTS OF UNANTICIPATED TAX-FINANCED INCREASE IN MONETARY GROWTH

% change in	10% increase in home and foreign monetary growth		10% increase in home monetary growth			
			[PPP]		Imperfect substitution	
	Impact	Final	Impact	Final	Impact	Final
$U, \bar{C}, C_D$	−2·217	0·111	−6·703	2·105	−5·061	2·105
$U^*, \bar{C}^*, C_D^*$	−2·217	0·111	4·486	−1·994	2·844	−1·994
C_M	−2·217	0·111	−6·703	2·105	−13·681	8·176
C_M^*	−2·217	0·111	4·486	−1·994	11·464	−8·065
ν	0·0	0·0	0·0	0·0	8·620	−6·072
$b^{a,b}$	0·0	0·0	3·443	−1·262	2·111	−1·261
I	7·390	4·454	3·695	2·227	−5·434	2·227
I^*	7·390	4·454	3·695	2·227	1·956	2·227
K^c	0·0	4·454	0·0	2·227	0·0	2·227
K^{*c}	0·0	4·454	0·0	2·227	0·0	2·227
M	−121·425	−119·098	−126·862	−120·000	−124·911	−120·000
M^*	−48·570	−46·214	5·437	0·902	3·4859	0·902
F/A^a	0·0	0·0	0·0	26·230	0·0	26·230
A	−48·570	−46·214	−50·745	−21·058	−49·965	−21·058
A^*	−48·570	−46·214	2·175	−25·156	1·395	−25·156
H	13·234	15·553	7·978	9·826	9·906	9·826
H^*	13·234	15·553	5·256	5·727	3·328	5·727
Z	−36·591	−40·565	−27·309	−39·025	−30·639	−39·025
Z^*	−36·591	−40·565	−9·282	−1·540	−5·952	−1·540
p, p_c	9·537	10·0	9·613	10·0	9·588	10·0
p^*, p_c^*	9·537	10·0	−0·076	0·0	−0·051	0·0
welfare[d]	−26·059	−3·209	−30·734	−22·316	−29·031	−22·316
welfare*[d]	−26·059	−3·209	4·676	−1·414	2·972	−1·414

[a] For this variable, the arithmetic change in percentage points is given.
[b] This variable is the ratio of the balance of trade to gross output, that is $(Y-C-I-G)/Y$.
[c] The arithmetic changes in the real interest rate (in percentage points) and percentage change in output and the real wage are, respectively, −0·104, 0·2 and 0·2 times the percentage changes in the capital stock.
[d] Welfare is defined as $\bar{C}^{\gamma}M^{1-\gamma}$.

immediately increases the opportunity cost of holding real money balances, so that real money balances and non-human wealth fall on impact by 121·43 and 48·57 per cent, thereby overshooting their steady state by 2·33 and 2·36 per cent, respectively. The increase in seigniorage revenues permits a cut in taxation of 36·59 per cent, which gradually rises to 40·56 per cent, and an increase in human wealth of 13·23 per cent, which gradually rises to 15·55 per cent. The overshooting of real money balances can also be seen in the behaviour of total wealth and consumption: on impact they fall by 2·22 per cent, and in the long run they increase by 0·11 per cent. Instantaneous welfare also overshoots, since on impact it falls by 26·06 per cent and in the long run by 23·73 per cent.

Table 2 also shows the impact and steady-state effects of a tax-financed increase of 10 percentage points in home monetary growth. The effects on the real interest rate, investment, capital stock, output and the wage rate and on the global averages of all other variables are exactly half of what they are under a joint increase in monetary growth. In other words, in the long run there is an interdependent Mundell–Tobin effect, so that a unilateral increase in monetary growth boosts investment and production at home and abroad. At home the increase in seigniorage revenues permits a short-run cut in taxation of 27·31 per cent, which increases human wealth by 7·98 per cent. On impact, home real money balances and non-human wealth fall by 126·86 and 50·75 per cent, which ensures that home total wealth and consumption fall by 6·70 per cent. Abroad, the anticipation of higher wage rates, lower taxation and lower interest rates boosts human wealth on impact by 5·26 per cent. Foreign real money balances and non-human wealth increase by 5·44 and 2·18 per cent on impact. Hence foreign total wealth and consumption increase by 4·49 per cent on impact. Both at home and abroad, real money balances and total wealth overshoot their equilibrium values, so that total wealth and consumption at home and abroad misadjust in the short run. This causes instantaneous welfare at home to fall by 30·73 per cent on impact and therefore to overshoot by 8·42 per cent, and instantaneous welfare abroad to increase by 4·68 per cent on impact and to fall by 1·41 per cent in the long run.

IV. Imperfect Substitution between Home and Foreign Goods

So far, the two-country model discussed in this paper incorporated the Law of One Price. Here the unrealistic assumption of purchasing power parity is replaced by the assumption of imperfect substitution between home and foreign goods. It is also assumed that each country is completely specialized in production. Real variables are deflated by the producers' price level, P. This means that the analysis of Sections I(b)–(e) is as before. The main changes occur in Section I(f).

The first stage of the consumer's decision problem is to decide on its total consumption and saving, and therefore it has an intertemporal nature (see Section I(b)). The second stage is concerned with how much to consume of home goods, C_D, and foreign goods, C_M. With Cobb–Douglas preferences, consumers choose C_D and C_M to maximize the utility function $\bar{C}=(C_D/\omega)^{\omega}(C_M/(1-\omega))^{1-\omega}$ subject to the static budget constraint $PC_D+P^*EC_M=C$ where E denotes the nominal exchange rate. This yields $C_D=\omega C$ and $C_M=(1-\omega)C/\nu$ where the real exchange rate is defined as $\nu\equiv P^*E/P$. Upon substitution into the utility function, one obtains the consumer price index (CPI) as $P_C=P^{\omega}(P^*E)^{1-\omega}$ so that $C_D=\omega^{1-\omega}\bar{C}$ and $C_M=(1-\omega)\nu^{-\omega}\bar{C}$. To keep matters simple, it is assumed that governments have the same preferences over home and foreign goods as the private sector, so real government spending on home goods is given by $G_D\equiv\omega G$ and that on foreign goods is given by $G_M=(1-\omega)G$. Equation (24) is replaced by the condition for equilibrium in the home goods market,

$$\begin{aligned}(39)\qquad Y&=C_D+G_D+I+C_M^*+G_M^*\\&=C+G+I+[C_M^*+G_M^*-\nu(C_M+G_M)],\end{aligned}$$

and the condition for equilibrium in the foreign goods market,

$$\begin{aligned}(40)\qquad Y^*&=C_D^*+G_D^*+I^*+C_M+G_M\\&=C^*+G^*+I^*+[C_M+G_M-(C_M^*+G_M^*)/\nu],\end{aligned}$$

where the terms in square brackets denote the balances of trade. Similarly, equation (25) describing the current-account dynamics is replaced by

$$\text{(41)} \qquad \dot{F} = (r-n)F + Y - C - G - I$$
$$= (r-n)F + [C_M^* + G_M^* - \nu(C_M + G_M)],$$

where $F \equiv (B-D)$ and $F^* = -F/\nu$. Real non-human wealth of home agents is given by $A = K + M + D + F$ and that of foreign agents is given by $A^* = K^* + M^* + D^* - F^*$. The condition for uncovered interest parity becomes $r + p = r^* + p^* + e^e$ or $r = r^* + \dot{\nu}^e/\nu$.

The complete two-country model with imperfect substitution between home and foreign goods is particularly simple when the share of imported goods is 50 per cent ($\omega = \frac{1}{2}$), because then $r = r^*$ and therefore $K = K^*$, $Y = Y^*$ and $w = w^*$. Subtraction of (39) and (40) then yields $\nu = 1$, so that $P_C = P = P^*E$. In other words, the special case $\omega = \frac{1}{2}$ is observationally equivalent to the purchasing power parity model discussed in Sections I–III. The general case of $\omega > \frac{1}{2}$ can be summarized by ten ordinary differential equations in terms of K, K^*, F, ν, U, U^*, M, M^*, D and D^*, where the first three variables are assumed to be predetermined and the remainder are assumed to be non-predetermined.[4] Alternatively, one obtains a sub-system for the global averages $(K^a, U^a, M^a, D^a)'$, and an independent sub-system for the global differences, $(K^d, F, \nu, U^d, M^d, D^d)'$. Table 1 shows that the eigenvalues associated with the global averages for the tax-financed case are the same as under purchasing power parity. This is not so for the global differences; there are now two stable eigenvalues associated with K^d and F and three unstable eigenvalues associated with ν, U^d and M^d. The global differences now adjust even more slowly; that is, they take about 375 rather than 253 time-units to settle down within 0·1 per cent of the steady state.

Table 2 compares the effects of tax-financed increases in monetary growth under imperfect substitution between home and foreign goods and under purchasing power parity (PPP). The dynamic effects of an increase in home monetary growth are portrayed in Figures 1, 2 and 3. The main point to notice is that with imperfect substitution the real exchange rate, ν, misadjusts on impact for a monetary expansion; it depreciates by 5·35 per cent on impact and appreciates by 3·17 per cent in the long run. The reason is that the monetary

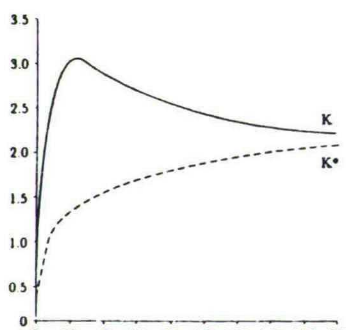

FIGURE 1. Effects of a 10 per cent increase in monetary growth on the capital stocks.

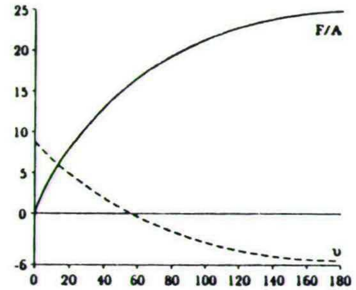

FIGURE 2. Effects on a 10 per cent increase in monetary growth on net foreign assets and the real exchange rate.

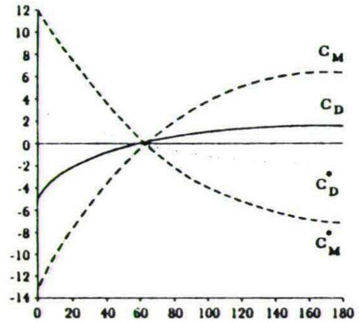

FIGURE 3. Effects of a 10 per cent increase in monetary growth on home and foreign consumption of home and foreign goods.

expansion leads in the short run to surpluses on the balance of trade and to accumulation of net foreign assets, hence in the long run the economy can afford to finance a deficit on the balance of trade with the interest revenues from abroad and to have a long-run appreciation of the real exchange rate. Over the adjustment period the real exchange rate does and is expected to appreciate, so that there is a real interest rate differential in favour of the home country and thus the home capital stock exceeds the foreign capital stock. Table 2 also shows that one of the main effects of the volatility of the real exchange rate under imperfect substitution between home and foreign goods is that there is less volatility in the other variables than there would be under purchasing power parity. Joint changes in economic policy do not affect the real exchange rate or the current account and thus yield the same outcomes under purchasing power parity as under imperfect substitution between home and foreign goods. These outcomes are identical to the sum of the effects of a unilateral increase in monetary growth on home outcomes *plus* the effects on foreign outcomes, so that they can be 'eye-balled' directly from Figures 1, 2 and 3.

V. CONCLUDING REMARKS

A two-country optimizing model with money, capital accumulation, floating exchange rates, uncovered interest parity, perfect foresight, finite lives and population growth has been formulated. For the special case of a zero birth rate, the discount rate used to calculate human wealth is the same as the discount rate used to calculate non-human wealth and government debt. It follows that for this case individuals are indifferent between tax finance and bond finance or money finance, so that Ricardian debt-neutrality and Sidrauski super-neutrality hold. Note that these neutralities occur in economies where the probability of death equals the rate of population decline. Sufficient conditions for these neutralities are infinite lifetimes and no population growth combined with the absence of an intergenerational bequest motive. The general case of non-zero birth rates is best analysed by decomposing the system into global averages and global differences. The main result of this paper is to provide a micro foundation of the interdependent Mundell–Tobin effect. This means that a tax-financed increase in monetary growth (that is, when seigniorage is distributed through helicopter drops of money) leads to a fall in the world real interest rate and thus to an increase in capital accumulation and output throughout the world. A home monetary expansion leads in the long run to an increase in home consumption, a fall in foreign consumption, a home balance-of-trade deficit and an increase in home holdings of net foreign assets. If the monetary expansion occurs through open-market operations (that is, when money is distributed through governments purchasing bonds), money is super-neutral. Hence a bond-financed increase in monetary growth leads to a one-for-one increase in inflation and the nominal interest rate and has no real effects.

An interesting area for further research is the optimal determination of fiscal policy (see Calvo and Obstfeld, 1988) and of monetary policy. This raises the issue of how the welfare of different generations should be weighed in order to construct a social welfare function. The problem of time inconsistency arises because central banks have an incentive to levy a surprise inflation tax. Obviously, the problem of optimal economic policy needs to be considered in an interdependent world and therefore issues of international policy coordination emerge. Most studies on international policy coordination have focused on monetary disinflation in two-country, real-exchange-rate overshooting models (e.g. Miller and Salmon, 1985; Currie and Levine, 1985; Oudiz and Sachs, 1985; Rogoff, 1985). However, such models imply *ad hoc* welfare functions and therefore do not permit a proper game-theoretic analysis of time consistency and the merits of international policy coordination. In two-country optimizing models of optimal taxation, one finds that in the absence of international cooperation government spending is excessive (Kehoe, 1986, 1987; van der Ploeg, 1987) and monetary growth is too high (van der Ploeg, 1988a). Furthermore, international policy coordination can aggravate the problems of credibility and time inconsistency so that cooperation between governments in the absence of pre-commitment *vis-à-vis* the private sector leads to excessive monetary growth and inflation and can thus be counter-productive (Rogoff, 1985; van der Ploeg, 1988a). Obviously, it is interesting to investigate the scope for international policy coordination within the context of the particular two-country model developed in this paper. An *ad hoc* analysis shows that, in the absence of international policy coordination, monetary growth is too low (van der Ploeg, 1990). However, the paper shows that an increase in home monetary growth may well be a beggar-thy-neighbour policy;

for, despite the fact that capital increases, foreign consumption falls and therefore, in the absence of international policy coordination, there may well be an inflationary bias in monetary growth.

APPENDIX

The world of super-neutrality and debt-neutrality discussed in Section II is now abandoned in favour of a world with strictly positive birth rates. This involves the full system (1)-(8). However, when the nonlinear system (1)-(8) is linearized around a *symmetric* steady state (around $\theta = \theta^*$ and $G = G^*$), it can be decoupled into a sub-system for the global averages and another sub-system for the global differences (*cf.* Aoki, 1981).

The state-space vector of global averages is $\mathbf{x}^a \equiv (K^a, U^a, M^a, D^a)'$ and the instrument vector of global averages is $\mathbf{u}^a \equiv (\theta^a, G^a, \xi_0^a)'$, where a global average is defined as the deviation of the arithmetic average of the home and foreign level from its steady-state level ($K^a \equiv K - K(\infty)$ and, say $U^a \equiv \frac{1}{2}[U - U(\infty)] + \frac{1}{2}(U^* - U^*(\infty)]$). The linearized sub-system for the global averages can then be written as

$$\text{(A1)}\quad \dot{\mathbf{x}}^a = \begin{bmatrix} r-n & -\gamma & 0 & 0 \\ Uf'' - (n+\beta)(\alpha+\beta) & r-\alpha & -(n+\beta)(\alpha+\beta) & -(n+\beta)(\alpha+\beta) \\ Mf'' & -(1-\gamma) & r+\theta-n & 0 \\ -Df''\xi & 0 & \theta\xi & -(r-n)\xi \end{bmatrix} \mathbf{x}^a + \begin{bmatrix} 0 & -1 & 0 \\ 0 & 0 & 0 \\ M & 0 & 0 \\ M\xi & -\xi & \xi \end{bmatrix} \mathbf{u}^a = \mathbf{A}^a\mathbf{x}^a + \mathbf{B}^a\mathbf{u}^a$$

where $\xi \equiv 1/(\xi_1 - 1) > 0$. The sub-system of global averages, (A1), corresponds to the description of a closed world economy, and therefore issues such as current-account dynamics do not feature. The saddlepoint property (e.g. Buiter, 1984) of this perfect-foresight sub-system requires two eigenvalues with negative real parts and two eigenvalues with positive real parts corresponding to two backward-looking (predetermined) variables K^a and D^a, and two forward-looking (jump) variables U^a and M^a, respectively. The product of the four eigenvalues associated with the sub-system of global averages is

$$\Delta^a \equiv \det(\mathbf{A}^d)$$
$$= \{-(r-n)\Delta_{TF}^a + (n+\beta)(\alpha+\beta)[(r-n)(1-\gamma)\theta - \gamma f''(\theta M + (r+\theta-n)D)]\}\xi,$$

where the product of the three eigenvalues[5] associated with the sub-system for the case of tax-finance ($\xi \to 0$, $\dot{D}^a = 0$) is given by

$$\Delta_{TF}^a \equiv \gamma(r+\theta-n)Uf'' + (n+\beta)(\alpha+\beta)\{\gamma Mf'' + (1-\gamma)[\theta - (w-Z)/M]\}.$$

Upon substitution of Δ_{TF}^a into Δ^a, we have

$$\Delta^a = -\xi\{\gamma(r-n)(r+\theta-n)Uf''$$
$$+ (n+\beta)(\alpha+\beta)[\gamma f''(r+\theta-n)(D+M) - (r-n)(1-\gamma)(w-Z)/M]\} > 0,$$

which is consistent with the saddlepoint property (given that $r - n > 0$ is assumed to hold).[6]

The state-space vector of global differences is $\mathbf{x}^d \equiv (F, U^d, M^d, D^d)'$ and the instrument vector of global differences is $\mathbf{u}^d \equiv (\theta^d, G^d, \xi_0^d)$, where a global difference is defined as the arithmetic difference of the home and foreign level from its steady-state level (e.g. $U^d \equiv [U - U(\infty)] - [U^* - U^*(\infty)]$). The linearized sub-system for the global differences can then be written as

$$\text{(A2)}\quad \dot{\mathbf{x}}^d = \begin{bmatrix} r-n & -\frac{1}{2}\gamma & 0 & 0 \\ -2(n+\beta)(\alpha+\beta) & r-\alpha & -(n+\beta)(\alpha+\beta) & -(n+\beta)(\alpha+\beta) \\ 0 & -(1-\gamma) & r+\theta-n & 0 \\ 0 & 0 & \theta\xi & -(r-n)\xi \end{bmatrix} \mathbf{x}^d + \begin{bmatrix} 0 & -\frac{1}{2} & 0 \\ 0 & 0 & 0 \\ M & 0 & 0 \\ M\xi & -\xi & \xi \end{bmatrix} \mathbf{u}^d = \mathbf{A}^d \mathbf{x}^d + \mathbf{B}^d \mathbf{u}^d.$$

The sub-system of global differences, (A2), does not depend on global activity variables, so that the current-account dynamics and the capital-stock dynamics are decoupled and can be analysed separately. The saddlepoint property requires two eigenvalues with negative real parts, associated with the predetermined variables F and D^d, and two eigenvalues with positive real parts, associated with the jump variables U^d and M^d. The product of the four eigenvalues associated with the sub-system of global differences is

$$\begin{aligned}\Delta^d \equiv \det(\mathbf{A}^d) &= [-(r-n)\Delta^d_{TF} + (n+\beta)(\alpha+\beta)(r-n)(1-\gamma)\theta]\xi \\ &= (n+\beta)(\alpha+\beta)(1-\gamma)(r-n)(w-Z)\xi/M \geq 0,\end{aligned}$$

where the product of the three eigenvalues associated with the sub-system for the case of tax-finance is given by

$$\Delta^d_{TF} \equiv -(n+\beta)(\alpha+\beta)(1-\gamma)(w-Z-\theta M)/M,$$

which is consistent with the saddlepoint property.

The comparative statics of the steady state makes use of $d\mathbf{x}^a(\infty)/d\mathbf{u}^a = -(\mathbf{A}^a)^{-1}\mathbf{B}^a$ and $d\mathbf{x}^d(\infty)/d\mathbf{u}^d = -(\mathbf{A}^d)^{-1}\mathbf{B}^d$, so that

$$\text{(A3)}\quad d\mathbf{x}(\infty)/d\mathbf{u} = -\tfrac{1}{2}[(\mathbf{A}^a)^{-1}\mathbf{B}^a + (\mathbf{A}^d)^{-1}\mathbf{B}^d]$$

$$\text{(A4)}\quad d\mathbf{x}^*(\infty)/d\mathbf{u} = -\tfrac{1}{2}[(\mathbf{A}^a)^{-1}\mathbf{B}^a - (\mathbf{A}^d)^{-1}\mathbf{B}^d].$$

These expressions for the steady-state multipliers can be evaluated analytically with the aid of Cramer's rule. Application of (A3)-(A4) to (36)-(38) yields

$$\text{(A5)}\quad [dU(\infty)/d\theta]_{TF} = -\tfrac{1}{2}(n+\beta)(\alpha+\beta)(r-n)M\frac{\Delta^a_{TF}+\Delta^d_{TF}}{\Delta^a_{TF}\Delta^d_{TF}} > 0$$

$$\text{(A6)}\quad [dU^*(\infty)/d\theta]_{TF} = \tfrac{1}{2}(n+\beta)(\alpha+\beta)(r-n)M\gamma f''\frac{(r+\theta-n)U+(n+\beta)(\alpha+\beta)M}{\Delta^a_{TF}\Delta^d_{TF}} < 0,$$

so that $[dC(\infty)/d\theta]_{TF} \geq 0$ and $[dC^*(\infty)\, d\theta]_{TF} < 0$. Similarly,

$$\begin{aligned}\text{(A7)}\quad [dM(\infty)/d\theta]_{TF} &= -\tfrac{1}{2}M\{\gamma Uf'' + (n+\beta)(\alpha+\beta)[1-\gamma-(w-Z)/U](1+\Delta^a_{TF}/\Delta^d_{TF})\}/\Delta^a_{TF} \\ &\leq -\tfrac{1}{2}M\gamma Uf''/\Delta^a_{TF} < 0\end{aligned}$$

and

$$\begin{aligned}\text{(A8)}\quad [dM^*(\infty)/d\theta]_{TF} &= -\tfrac{1}{2}M\{\gamma Uf'' + (n+\beta)(\alpha+\beta)[1-\gamma-(w-Z)/U](1-\Delta^a_{TF}/\Delta^d_{TF})\}/\Delta^a_{TF} \\ &\geq -\tfrac{1}{2}M\gamma Uf''/\Delta^a_{TF}\end{aligned}$$

as $\Delta^a_{TF} < \Delta^d_{TF} \leq 0$ (and $w \geq Z + (r+\theta-n)M$ is assumed to hold).

Although the comparative dynamics can, in principle, be evaluated analytically, it is cumbersome, and therefore dynamic adjustment paths for the endogenous variables are evaluated numerically. The transient perfect-foresight trajectories of the linearized model are calculated with the aid of the computer program PSREM developed by Markink and van der Ploeg (1988). It is easy to show that the impact effects on the jump variables, for the global averages, are given by

$$\text{(A9)} \quad \mathbf{x}_j^a(0) = \begin{bmatrix} U^a \\ M^a \end{bmatrix} = -\mathbf{N}_{jj}^{-1}\Lambda_j^{-1}(\mathbf{N}_{jp}\mathbf{N}_{jj})\mathbf{J}\mathbf{B}^a\mathbf{u}^a,$$

where Λ_j is a diagonal matrix with the two eigenvalues with positive real roots of $\mathbf{A}^a$ as its elements, $(\mathbf{N}_{jp}|\mathbf{N}_{jj})$ is a matrix whose rows contain the row-eigenvectors associated with the two eigenvalues in Λ_j, and $\mathbf{J}$ is a matrix of zeroes and ones that permutes the second and fourth row of $\mathbf{B}^a\mathbf{u}^a$. A similar expression is used for the jumps in the global differences.

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NOTES

1. When the central banks care about output or consumption and inflation, one can show that, in the absence of international policy coordination, monetary growth and inflation are too low, real interest rates are too high, and capital, output and employment are too low. Since an increase in monetary growth is a locomotive policy, each country attempts to transfer the burden of reducing the world real interest rate to the other countries as this leads to an increase in activity without an increase in inflation (van der Ploeg, 1990).
2. However, there are no results on the effects of money-financed increases in government spending within two-country overlapping-generations models.
3. When money yields no utility ($\gamma = 1$), it corresponds to the unbacked and intrinsically useless asset, fiat money, studied in the literature on money in overlapping-generations models. A monetary equilibrium then exists only when the rate of growth of the per capita money supply is less than minus the pure rate of time preference ($\theta < n - \alpha$), and thus a positive growth in the nominal money supply can occur only when the non-monetary economy is dynamically inefficient (Wallace, 1980; Weil, 1989a, b).
4. This assumes that initially no gross foreign assets are held, so that jumps in the real exchange rate do not lead to jumps in F.
5. The fourth eigenvalue is 0.
6. It is possible to examine under which conditions the saddlepoint property holds for the special case of tax finance. It will be assumed that wage income is sufficient to cover lump-sum taxes plus the interest forgone on holding real money balances (i.e. $w > Z - (r + \theta - n)M$), so that Δ_{7F}^a is negative. Hence the tax-finance system has either one stable and two unstable eigenvalues or three stable eigenvalues. Since the sum of the eigenvalues, $r - n + r - \alpha + r + \theta - n$, is positive (as $n < r \leq \alpha + \beta + n$ is assumed to hold), the second possibility is ruled out and therefore the saddlepoint property is satisfied.

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